Routing for Sensors with Parameters as used in Agricultural Field

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***Abstract*— Transmission of data from the source to the sink occurs as soon as the path is established and data transfer is scheduled. Routes could go down for various reasons some could be due to loss in energy, broken link, faulty nodes etc. This paper tries to enhance the network life by finding an energy efficient path so that the path once established is alive for long and avoiding path failure due to depletion of energy. The parameters used for the simulation is as used in agricultural field.**

***Index Terms*— Wireless sensor network, data transmission, agriculture, energy aware, routing.**

I. Introduction

Sensors are responsible for capturing, analyzing and transmitting information using radio signals. Sensor networks contain a base station usually called a sink and enormous number of other sensors which carry out the task of sensing and transmitting, along with relaying information of other nodes. Sensors are highly resource constrained, major being battery power, transmission range, data and program memory.

Scarcity of water is a major issue faced by the world. An awareness of water consumption is very much essential to avoid depletion of water in the water bed. Knowledge of water usage if provided to a farmer could help them in significantly improving the way water is managed [1-3]. Sensors placed in the soil could help in detecting the soil moisture; and this data collected by the network could help in regulating the water flow to the fields [2]. Analysis of data collected could help in predicting the yield and any new strategies can be adopted to overcome any associated problems. In this paper an energy aware protocol is developed to enhance the life of the network by selecting path with sufficient energy and taking actions if the path is vulnerable to failure.

II. Related Work

Sensors are application specific and can be used to continuously sample physical data like humidity, temperature, soil moisture etc. COMMON Sense Network is a project associated with monitoring the regulation of water supply to the field [3]. The sensors used here are placed at a depth of 15cm to 30cm and the moisture content is sensed. Based on this on- going project the path finding and path establishment algorithm NEWAODV is devised to overcome node failure using ns2.34. Part 3 deals with the best way to deploy sensors to enhance the network life. Part 4 deals with the routing algorithm for path search. Part 5 deals with the selection of the minimal and maximum hop count in the network. Part 6 deals with the minimum energy requirement for path maintenance. Part 7 deals with simulation and discussion.

COMMON-Sense Network is one such project associated with monitoring the regulation of water supply to the field [3]. This project uses AODV protocol [4] for path finding, establishment and maintenance. In this paper we try to improvise and make certain changes to AODV to suit the requirement for agricultural application using network simulator ns2.34. The new protocol is named as NEWAODV.

III. Deployment

Sensors can be deployed in the field in random order. In order to find a network which is cost effective various topologies have been studied. Figure 1 shows the grid, triangular and hexagonal topology. The topology is so chosen that they are placed in the hearing range of each other, and at the maximum only three sensors are able to listen to each other in hexagonal and only four are in the hearing range in the case of grid topology. Diagonally they are not able to hear each other.

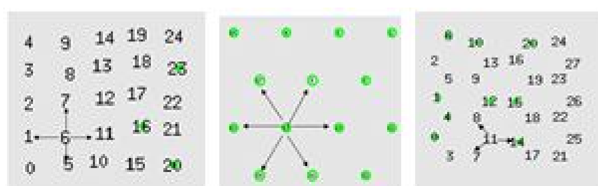

Figure 1. Various topologies

IV. Routing Algorithm for path search

Reactive route finding algorithm maintains a routing table in each node. Though this application has no mobile nodes, routes are computed dynamically so that new routes are found when the nodes go faulty by losing their energy. Control packets are used to trace the efficient path and data packet for transmission of data. In AODV two routing table are maintained one towards the source and one towards the destination [4]. Here we are maintaining one routing table reducing some of the overhead. Sections below are the extension to the earlier carried out work [5].

A. Path discovery, establish and maintenance

The NEWAODV_BEACON packet is broadcast from the

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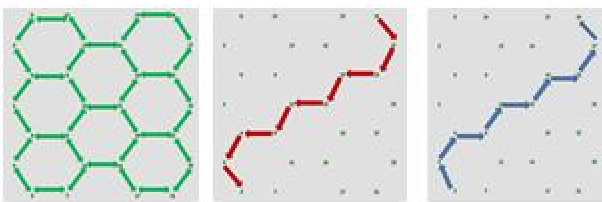
source to all its neighbors, the neighbors in turn broadcast the signal to its neighbor until it reaches the sink as shown in Figure 2a.

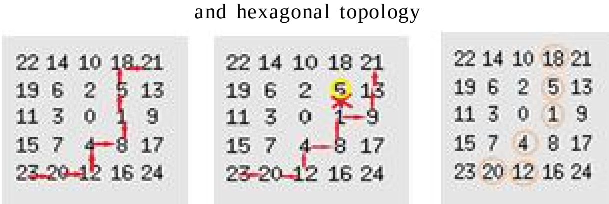
NEWAODV_BEACON packet on reaching the sink will send the path establish packet back to the source which establishes the reverse path to the source as shown in Figure 2b. Figure 2c shows the path established to transfer data.

Data is sent continuously using a constant bit rate. The interval to send the data is 300 secs. This rate is sufficient to check if the field is irrigated, once every 5 minutes. The path for sending data is unicast and is based on the next hop value entered in the routing table during path establishment. The path which is established between source and sink is used to continuously send the data from the source to the sink until any link failure occurs. On the occurrence of the link failure a new path is again established using the broadcast signal NEWAODV_BEACON from the node where the link failure occurred. This process is continued until there is no path to the sink from the source.



(a) **(b)** **(c)**

Figure 2. Path search (a), establish (b) and data send(c) for square and hexagonal topology



(a) (b) (c)

Figure 3. Various stages of path establishment for the nodes losing their energies

Figure 3a shows the path established during the first round, figure 3b during second, and so on. The yellow colored node represents the node which has lost its energy. From the figure 3 it is seen that a new path is established from the point of failure of the node. Similarly many nodes lose their energy along in the path resulting in figure 3c. Figure 3c shows that the nodes circled in brown have no energy in them. It also represents a case when there is no path between the source and the sink. In order to check if there is any available path to the destination, we can check if the hop count has reached the maximum possible hop count. If the topology is fixed then as shown in Section V we can predict if the hop count has exceeded the maximum possible hop count and declare there is no route to destination.

V. Minimum and Maximum Hop Count

To improve on the existing routing protocol, we check for two more conditions, that is the minimum hop count and maximum hop count. As we know beforehand the actual deployment topology, we can fix in the minimum hop count, if the deployment follows a specific pattern. For the square topology with size n* n, with sink and source in extreme corners of the network, as shown in Figure 4a, for n=5, the minimum hop count is 8 and Figure 4b, shows the maximum hop count =16. The nodes which are neighbors horizontally and vertically can transmit to each other. But diagonal transmission is not allowed. Figure 4a shows the minimum hop count from one end of the network to the other. Figure 4b shows the maximum hop count that is possible for the same network.

If the nodes are in the form of a grid structure with 4 nodes, minimum hop count is 2 across the ends of the network.

With network of 9 nodes (3*3) the minimum hop count is 4.

With 16 nodes, minimum hop count is 6.

In general, for an n* n grid network the minimum hop count is given by 2*(n-1).

Let i=1 for 0*0 node size, the maximum hop count is 0.

i=2 for a node size of 25 nodes (5*5); the maximum hop count is 16.

i=3 for node size of 9*9, maximum hop count is 48.

i=4 for node size of 13*13, maximum hop count is 96.

i=5 for size of 17*17, maximum hop count is 160.

Value of i increases by 1 for every 4^{th} increase in the size of the topology.

In general the maximum hop count for every 4^{th} increase in the size of the dimension along the horizontal and vertical for n*n node size is given by 2*i*(n-1).

For all n*n sized topologies the values are in between their corresponding range.

Based on the above findings, we find that if there is a loop, or the there is no path to the destination, if the above maximal hop count has exceeded.

Maximum hop count is given by 2*i*(n-1), where, i=2 for n=5, i=3 for n=9 i=4 for n=13 and so on for every increase of 4 in the value of n. This maximum hop count is the same as, the time to live of the network as given in the AODV protocol.

Minimum count helps to avoid unnecessary propagation of broadcast signal during path fetch. All intermediate nodes which have crossed minimum hop count can be further avoided from being propagated. The intermediate path search utilizes the minimum hop criteria. When no other path exists, the maximum hop count is utilized to find, the only available path. There is no path if the hop count exceeds the maximum hop count requirement between the source and the sink. Sometimes this could result in partitioning of the network into sub networks. Checking for the maximum hop count is sufficient to find if there exists any path between the source to the destination.

VI. Minimum Energy Requirement for route Discovery and Maintenance

Loss of data due to link failure can be avoided if there is an awareness of link likely to fail. One of the reasons for link failure is depletion of energy. Neighbor (sender), of the data is alerted of the node losing its energy. This can be done by

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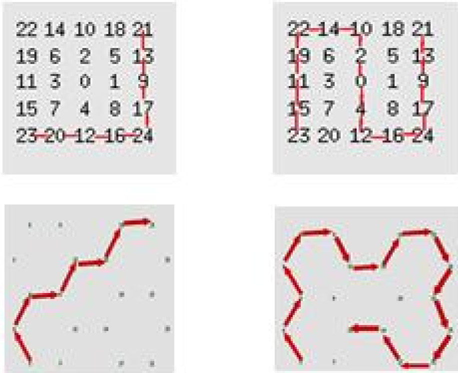

(a) (b)

Figure 4. Minimum and maximum path length in a grid topology of 5*5 nodes and hexagonal of 20 nodes

sending a signal to its neighbor to transmit the data from the node previous to this failing node. Ref. [13-14] discusses parameter selection for sensor network.

Tinynode is the mote used in the agricultural field from the manufacturers of Shockfish [15]. This mote is chosen as it provides longer distance of transmission as compared to the mica motes. The minimum energy requirement is derived as follows,

Two alkaline batteries of 1.5V are used as the battery power for the Tiny node.

The power to transmit is 33mA * 3V =99mW (1)

Power to receive is 14mA * 3V= 42mW (2)

Idle power is 2mA * 3V= 6mW (3)

Sleep power 1µA * 3V = 3 µW (4)

There are two kinds of signals. One the control signal during path fetch and data send with the rate 1Mbps.

A. Energy for control packet

The packet size at the MAC includes the common header (10 bytes), the IP header (10 bytes), routing header (28 bytes), and the MAC header (58 bytes).

Packet size at MAC layer =106 bytes (5)

Transmit time = Data Packet Size * 8/ Data rate. (6)

Control signals are sent at 1Mbps.

From equation (5) and (6) with control signal rate at 1Mbps we get,

Transmit time = 106 *8/1*10^6= 0.000848s (7)

Energy consumed is given by,

Energy = Power * Time (8)

Using the values from the equation (1) and equation (7) in equation (8) we get,

Energy for transmission is = 0.099W * 0.000848s
= 0.000084Ws (9)

Using the values from equation (2) and (7) in equation (8) we get,

Energy for reception is = 0.042W *0.000848s
= 0.000036Ws (10)

During a single control signal transmission and reception the amount of energy that is consumed is 0.000071Ws.

B. Energy requirement for data transfer

Considering the data packet size as 70 bytes, we have the packet size at the routing layer to be 90 bytes on adding the packet header from the upper layer with 20 bytes (IP + common header= 20 bytes). The total packet size is 90 bytes + 58 bytes from mac layer

The transmit time = 148 * 8 / 1 *10^6 = 0.001184s (11)

From equation (1) and equation (11) we get,

Energy for transmission is

= Transmit Power * Transmission time
= 0.099W * 0.0011845s
= 0.0001171Ws (12)

Energy for reception is = 0.042W * 0.0011845s
= 0.00039375Ws (13)

Transmit energy for MAC RTS of 44bytes
=44*8/1Mbps *0.099=0.000035Ws (14)

Receive energy for MAC CTS of 38bytes
=38*8/1Mbps *0.042=0.000013Ws (15)

Receive energy for MAC ACK or 38 bytes
=0.000013Ws (16)

Idle energy =Idle period * Idle energy
= 300* 0.002 =0.6Ws (17)

The sequence of operation during data transfer involves obtaining the data packet from the upper layer up to

MAC and then physical layer from the application layer. For transmitting the data CTS is sent and RTS is obtained in response. On sending data to the neighboring node or destination node it sends an ACK packet.

During data transfer it should have sufficient energy to send data wait for idle period send another data. If the energy level is low inform its previous node about draining energy. So it should have enough energy to send a control signal.

Minimum energy required = Energy to transmit + CTS energy + RTS energy + ACK+ control packet to send in case of failure + idle energy+ energy to receive (18)

Using values from equation (12) to equation (17) along with equation (9), in equation (18) we have, minimum required energy =

0.000117 + 0.000013+ 0.000035+ 0.000013+ 0.000084+ 0.6

+0.000036= 0.600298 Ws. (19)

This is the minimum data threshold energy, required to establish a path for data transfer.

C. Energy requirement to send control packet

During path fetch control signals are transmitted to find the path to the destination from the source. The control packet size in the routing layer is 28. With IP and common at 10 and 10 respectively and at MAC size of 58 bytes totally will result in a control packet size of 106 bytes at MAC layer. Address resolution packet size for send is 86 bytes and receive 28 bytes

Energy for the ARP for sending = 86*8/1Mbps *0.099
= 0.000068Ws (20)

Energy for the ARP for receiving= 28*8/1Mbps *0.042
= 0.0000094Ws (21)

The steps involved during path discovery involve sending the control signal from the Application layer to the Network layer followed by MAC layer and the Physical Layer.

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ARP is invoked if the address for the node is resolved for the first time.

With this information, minimum energy required to establish a path involves, enough energy to send the control signal to the next node, receive the path establish packet and send data. =Control signal send + control signal receive (during path establish) + Address resolution protocol- send + ARP receive +Energy enough to send data.

=0.000084+0.000036+0.000068+0.000009+0.600298 =0.600495Ws

This is the minimum path threshold energy each node should have so that it can establish a path. Nodes having less than this amount of energy will not be used for path establishment.

D. Energy requirement in the network

To establish a path the energy consumption is 0.000084Ws for transmit. This is being received by four of the neighbors in the grid topology and 3 neighbors is hexagonal topology. For every broadcast control signal there will be around 4* receive energy + 1 * transmit energy.

At the maximum if every node has to transmit, n transmission exits and 4*n reception exists in the case of grid topology. Hence the maximum amount of energy consumed for transmission and reception during path search is n*0.000084 + 4*n* 0.000036.

For an n*n node topology, the number of corner nodes =4. These nodes can transmit to two neighboring nodes. The number of edge nodes other than the corner nodes is (n-2) * 4. These nodes can transmit to three neighboring nodes. The number of nodes which can transmit to all its four neighbors are (n-1)*(n-1).

Hence the maximum energy consumed to transmit n*n*Transmit energy in the whole network.

With 4 corners nodes sending, 2 neighbors accept. This result in 4*2 receives messages.

With (n-2) nodes at the edges, and along 4 sides, 3 nodes accept. So the total number of nodes accepting, when corner nodes transmit is 4(n-2) *3*Receive energy.

With (n-2)*(n-2) nodes transmitting, the receiving nodes are 4, total energy consumed is 4*(n-2) *(n-2) *Receive energy.

Hence maximum energy to receive by all the nodes in the whole network is (8+4(n-2)*3 + (n-2) (n-2) *4) * Receive energy.

= ($4n^2$-4n) * Receive energy.

Using this energy threshold values, we can formulate the algorithm as follows,

1. Start the path search using the control signal with a new sequence number from the source to the destination.
2. In each of the traversed node
2.1 Drop the control packet in the node which has energy less than the path threshold energy level.
2.2 Make an entry in the routing table for each source destination combination for each of the node traversed provided,
2.2.1The route to be searched is a new one with a new sequence number
2.2.2 With minimum hop count from those found so far between the corresponding source destination combination
2.2.3 For each entry made in the routing table a reverse routing table entry is made from current traversed node to its previous source node.
2.2.4Otherwise drop the control packet.
3. This process is repeated until it reaches the destination to drop the control packet.
4. If the hop count is more than the maximal hop count as computed in section 5, then drop the packet as there is no route from this node to the destination. Once the packet reaches the destination another control packet is started in the reverse direction from the destination to the source
5. The node traverses the path as specified in the reverse routing table to reach the destination. Once the control signal reaches the source, Data transmission starts from the source to the destination
6. In each node along the path,
6.1 If the node has at least the data threshold energy forward the data packet to the destination.
6.2 Otherwise, forward that data from the node and at the same time send a notification to the sender that the path is likely to fail and start a new path search.
7. This path search procedure continues until there is no path between the source and the destination.

TABLE I. SIMULATION PARAMETERS

Radio parameters	
Radio frequency	915 MHz
Antenna Height	1m (min. reqd. height 0.0819m)
Antenna Type	Omnidirectional –Quarter wave
Transmit Power	3.16 mW =5dBm
Receive Power	−104dBm@ 5dBm=3.98e-14W
Carrier Sense Threshold	−104dBm@ 5dBm
Capture Threshold	10 dBm
Gain of transmitting/Receiving antenna	1
Path loss	1
Transmitting distance	200m. as given in manual. 531m as calculated
Sensor parameters (Tiny Node)	
Transmit Power	0.099W=19.95dBm
Idle Power	0.006W=7.78dBm
Receive Power	0.042W=16.23dBm
Sleep Power	0.000003W=-25.2dBm
Battery (Alkaline battery of 1.5V)	
Battery supply	3V with 2 AA sized battery
Power consumption	0.0705W for 23.5mA discharge current
Energy consumption	20304J for 80hrs. of operation
Simulation parameter	
Simulation period	15724800seconds i.e. 6 months.
Simulation interval	300secs.
Topology	Hexagonal.
Network size	496
MAC	802.11

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V. Simulation Results and Discussion

The experiment is carried out using the parameters as shown in table 1. It is found that path with lower residual energy than the minimum threshold for path establish is dropped out during path search. This avoids path which have minimal energy from being used in the path search which could result in data not being able to reach the destination. Data threshold energy is the minimum required threshold energy required during data transfer. If the level in the energy goes below this value, then a control signal is sent to the previous node to start a new path search. This also avoids data being lost due to node failure due to energy.

Table 2 shows the results of the simulation. It is seen that knowing the minimum hop count can reduce the overall energy consumption during path search. The topology chosen was hexagonal with 496 nodes with extreme corners as source and sink.The comparison is done between AODV and NEWAODV protocol.

Table II. Simulated results

Parameter	Using known hop count (NEWAODV)	Finding min hop count (AODV)
Avg. Used energy	5.610461J	5.95833J
Avg. Transmit energy	0.828728J	0.964610J
Avg. Receive Energy	0.692135J	0.808971J
Avg. Idle Energy	4.089598J	4.184749J

During the first sequence path upto minimal hop count as deduced above can be used to find the path. If the path length is greater than the minimal path length, broadcast packets can be dropped. This avoid unnecessary transmission of broadcast signal which are of higher path length. During the course of path search if no path exists with minimal hop count, then new path are searched until it results in a disjoint network. It results in a case where there is no path between the source and the sink. The maximum number of times it can hop can be obtained from the relation as deduced in part V. In the current scenario 7 broadcast packets are dropped saving considerable amount of energy.

Conclusions

Applications where the network has to be alive for long require that path have to be chosen such that the transmission of data should continue as long as possible. In this paper the minimum energy requirement for path establishment is calculated. Every node in the network along which path is to be established should have enough threshold energy value for path establishment. This prevents path which have sufficient energy to establish a path but insufficient energy to transmit data from being utilized. Once data starts transmitting, it should have minimum energy to transmit data continuously. If it has energy less that the threshold data energy, then a control signal is sent to the parent to instigate a new path search process. This avoids loss of data due to energy depletion in the network. Prior awareness of minimum and maximum hop count could help in dropping broad cast packets which unnecessarily flood the network. During the initial sequence minimum hop count is used to find path, consecutively with no available path of minimal hop count, new path are found with hop count up to the maximal hop count. The process of finding new paths is repeated until the network gets partitioned and no path exists between the source and the sink. The path search consumes considerable amount of energy, which if carried out quite often will result in more amount of energy consumption in new path discovery. If a path with sufficient energy is found then the transmission of data for longer interval on a single path could be carried out. Backtracking and finding a new path before the energy goes low could avoid unnecessary loss of data transfer due to energy loss. It is observed that in the idle state large amount of energy is consumed. Nodes can be put to sleep when there is no transmission or reception to avoid energy expended due to the idle state.

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